1. IC4.1 Part 3: Climatology - Teleconnections

Instructor Notes: Welcome to the third sub lesson in Instructional Component 4, Climatology. In this lesson we'll discuss some "Teleconnections" and how they affect winter weather in the US.

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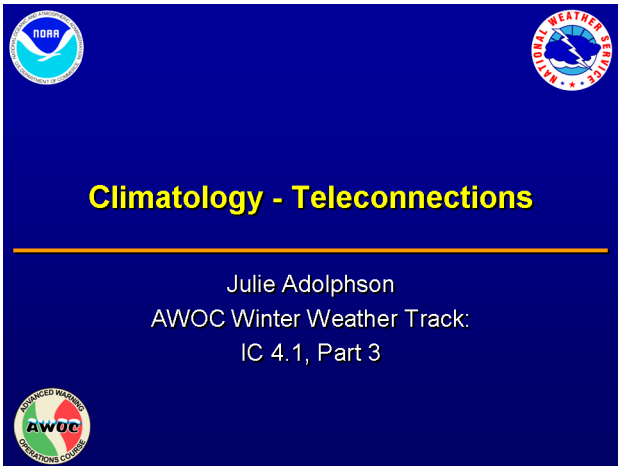

2. Purpose of Lesson 1.3

Instructor Notes: We've already discussed the importance of understanding slowly evolving systems on large space and time scales…El Niño, La Niña, Southern Oscillation and the MJO, in lessons 1.1 and 1.2. In this lesson, 1.3, we'll take a look at "teleconnections" which are correlations or "patterns" in space and time of atmospheric parameters such as sea level pressure or 500 mb heights. We'll take a look at a few of these patterns and see how they are monitored and what their effect is on U.S. weather. I should point out that while observing what "phase (positive or negative)" a particular teleconnection is currently in is straightforward, prediction is another matter all together, just as we saw with the MJO and ENSO.

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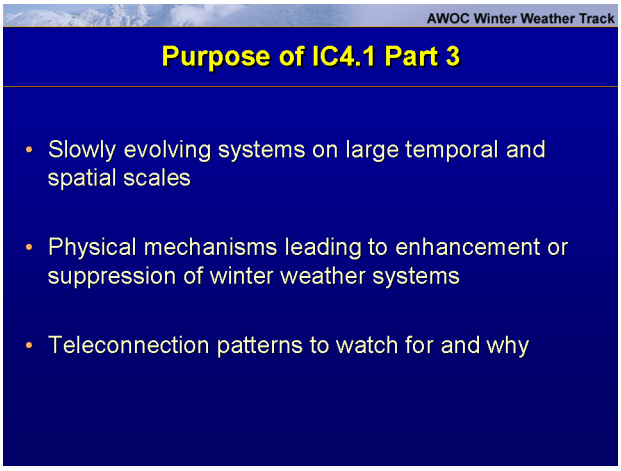

3. IC 4 Lesson 1.3 Learning Objectives

Instructor Notes: We will focus on helping you look at the "big picture" in space and time to help you assess the potential for upcoming winter storms in your area of responsibility. We'll see how these "slowly evolving" correlations, called teleconnections manifest themselves and how they influence weather in the US. We'll also see how these phenomena are monitored, and in later sections we'll take a look at resources you can use to assess the state of the climate system and what the latest predictions are for the medium and longer ranges.

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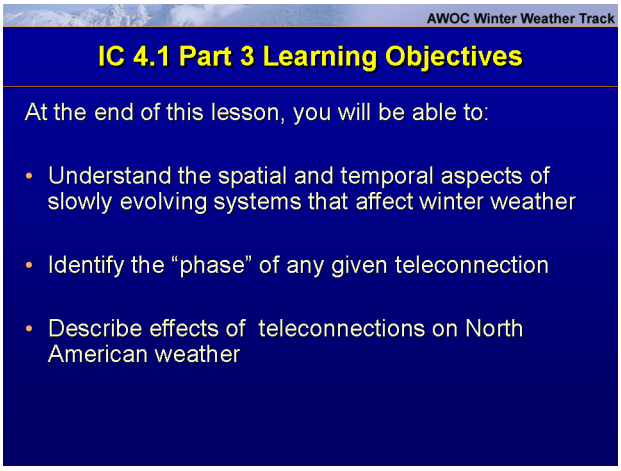

4. Performance Objectives

Instructor Notes: After this lesson you should be able to investigate the current state of the atmosphere in large temporal and spatial scales and correlate that to the potential for winter storms. Also, you will be able to determine the “mode” of the climate system and what to expect for the winter season in terms of temperature and precipitation anomalies (or lack thereof). You will understand the mechanisms that contribute to a higher or lower probability of winter storms in your area. Finally, you will be able to distinguish between different types of teleconnections and understand what significance they have in the winter for the US.

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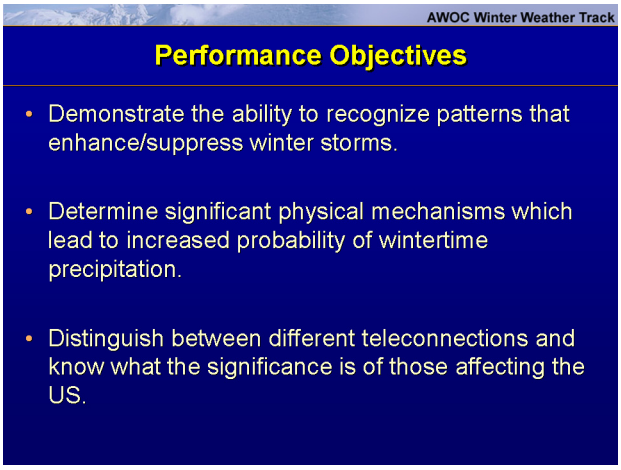

5. Lesson 1.3 Outline

Instructor Notes: In this lesson we will discuss “teleconnections.” We will define them, and find out where they occur, how we measure their state, and what is their effect is on U.S. weather.

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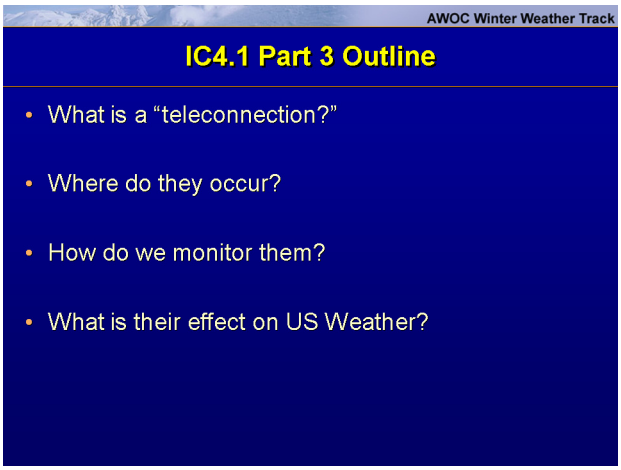

6. Teleconnections

Instructor Notes: A teleconnection is a strong statistical relationship between weather in different parts of the globe. For example, there appears to be a teleconnection between the tropics and North America during ENSO. There are several teleconnections that are important to the weather in the US. For example, Pacific-North American or PNA, the Arctic Oscillation or AO, the North Atlantic Oscillation or NAO, and Tropical Northern Hemisphere or TNH. We'll look at the patterns associated with these teleconnections and also look at "indices" which are used to determine whether the pattern is in a negative or positive phase. There are other teleconnections, such as the Pacific Decadal (or PDO) and the Antarctic Oscillation or AAO that we will not cover in this lesson. As I mentioned earlier, the predictability of teleconnections is very challenging…the mod-

els struggle to accurately predict these patterns, and much work is still needed even in the ensemble prediction system to improve the skill of predicting the "phase" and amplitude of any given teleconnection pattern. The term "teleconnection pattern" refers to a recurring and persistent, large-scale pattern of pressure and circulation anomalies that span vast geographical areas. Teleconnection patterns are also referred to as preferred modes of low-frequency (or long time scale) variability. Although these patterns typically last for several weeks to several months, they can sometimes be prominent for several consecutive years, thus reflecting an important part of both the interannual and interdecadal variability of the atmospheric circulation. Many of the teleconnection patterns are also planetary-scale in nature, and span entire ocean basins and continents. For example, some patterns span the entire North Pacific basin, while others extend from eastern North America to central Europe. All teleconnection patterns are a naturally occurring aspect of our chaotic atmospheric system, and can arise primarily as a reflection of internal atmospheric dynamics. Additionally, some of these patterns, particularly those over the North Pacific, are also sometimes forced by changes in tropical sea-surface temperatures and tropical convection associated with both the ENSO cycle (Mo and Livezey 1986, Barnston and Livezey 1991) and the Madden-Julian Oscillation (MJO). Teleconnection patterns reflect large-scale changes in the atmospheric wave and jet stream patterns, and influence temperature, rainfall, storm tracks, and jet stream location/ intensity over vast areas. Thus, they are often the culprit responsible for abnormal weather patterns occurring simultaneously over seemingly vast distances. For example, the 1995/ 1996 winter was very cold and snowy over much of eastern North America, while northern Europe and Scandinavia were cold and southern Europe/ northern Africa experienced very wet and stormy conditions. These conditions were all partly related to the same teleconnection pattern: a strong negative phase of the NAO. The Climate Prediction Center routinely monitors the primary teleconnection patterns and is involved in continuing research to better understand their role in the global climate system. Ten prominent teleconnection patterns can be identified in the Northern Hemisphere extratropics throughout the year, and all of these patterns have appeared previously in the meteorological literature (Barnston and Livezey 1987). References: (Mo, K. C., Livezey R. E., 1986: Tropical-extratropical geopotential height teleconnections during the Northern Hemisphere winter. Monthly Weather Review., 114, 2488-2515. Barnston, A. G., Livezey R. E., 1987: Classification, seasonality and persistence of low-frequency atmospheric circulation patterns. Monthly Weather Review.,115, 1083-1126. Barnston, A. G., Livezey R. E., Halpert M. S., 1991. Modulation of Southern Oscillation-Northern Hemisphere mid-winter climate relationships by the QBO. Journal of Climate., 4, 203-217.)

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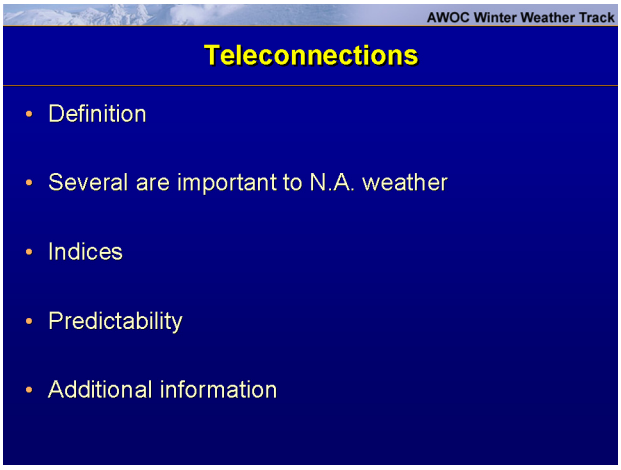

7. The Tropical/Northern Hemisphere (TNH)

Instructor Notes: The Tropical/ Northern Hemisphere (TNH) pattern was first classified by Mo and Livezey (1986), and appears as a prominent wintertime mode during December-February. The positive phase of the TNH pattern features above-average heights over the Gulf of Alaska and from the Gulf of Mexico northeastward across the western North Atlantic, and below-average heights throughout eastern Canada. The TNH pattern reflects large-scale changes in both the location and eastward extent of the Pacific jet stream, and also in the strength and position of the climatological mean Hudson Bay Low. Thus, the pattern significantly modulates the flow of marine air into North America, as well as the southward transport of cold Canadian air into the north-central United States.

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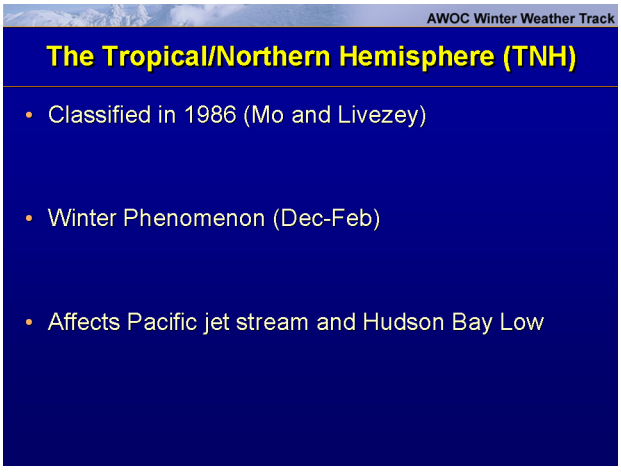

8. TNH (Continued)

Instructor Notes: The positive phase of the TNH pattern is associated with below-average surface temperatures throughout the western and central United States, and across central and eastern Canada. It is also associated with above-average precipitation

across the central and eastern subtropical North Pacific, and below-average precipitation in the western United States and across Cuba, the Bahama Islands, and much of the central North Atlantic Ocean. The negative phase of the TNH pattern is often observed during December and January during El Niño conditions (Barnston et al. 1991). One recent example of this is the 1994/95 winter season, when mature Pacific warm episode conditions and a strong negative phase of the TNH pattern were present. During this period, the mean Hudson Bay trough was much weaker than normal and shifted northeastward toward the Labrador Sea. Additionally, the Pacific jet stream was much stronger than normal and shifted southward to central California, well south of its climatological mean position in the Pacific Northwest. This flow pattern brought well above-normal temperatures to eastern North America and above-normal rainfall to the southwestern United States.

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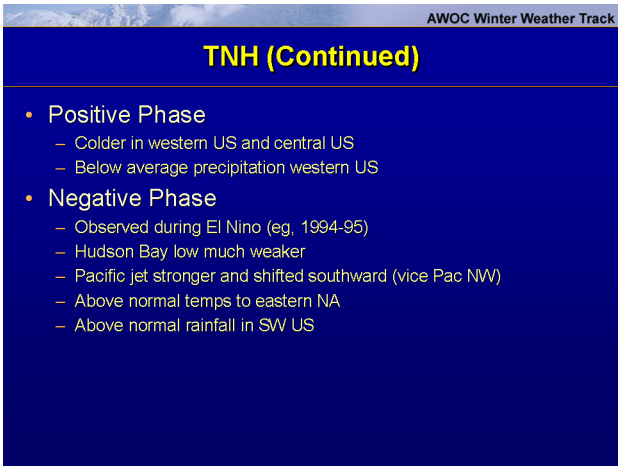

9. Height Anomalies for +TNH

Instructor Notes: This diagram of 500 mb height anomalies in January represents the positive phase of the TNH. The loading pattern (or statistical representation) for January is displayed so that the plotted value at each grid point represents the temporal correlation between the monthly standardized height anomalies at that point and the teleconnection pattern time series valid for the specified month. (note: figures on next 3 slides from http://www.cpc.ncep.noaa.gov/data/teledoc/tnh_map.shtml)

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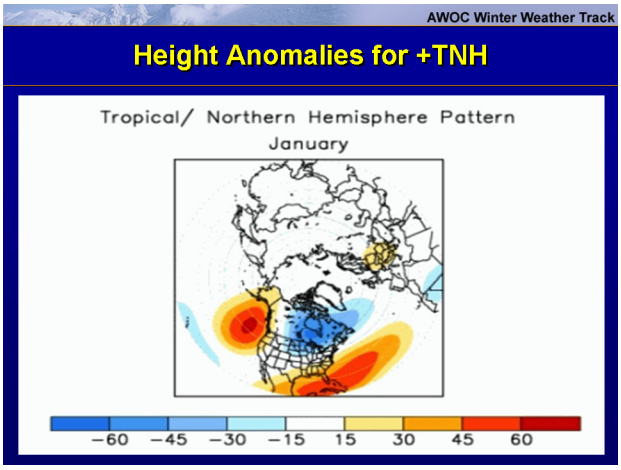

10. Positive Phase of TNH

Instructor Notes: Maps showing correlation during 1950-2000 between the teleconnection index and monthly surface temperature departures for the three months centered on the month of interest. For example, the January pattern shows the correlation between the January values of the teleconnection index and the monthly temperature departures during December, January, and February. Notice the blue, or colder area over much of the US and eastern Canada, which I mentioned previously.

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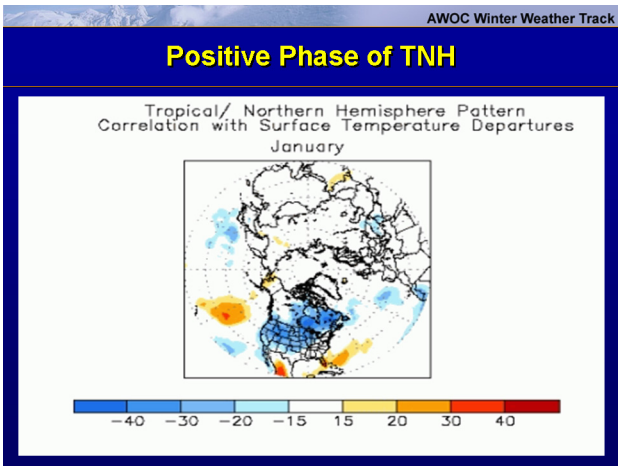
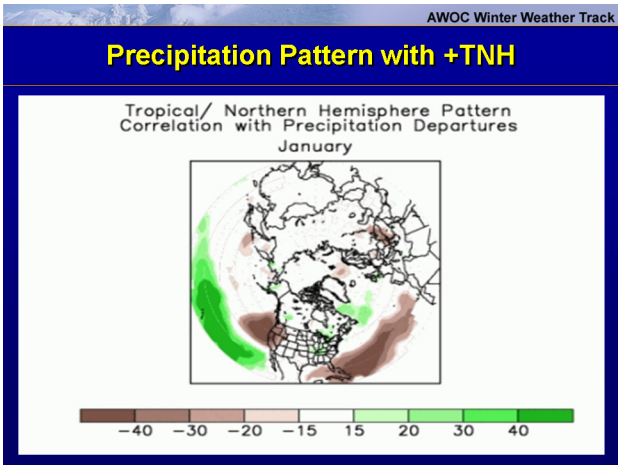


11. Precipitation Pattern with +TNH

Instructor Notes: Maps showing correlation during 1950-2000 between the teleconnection index and monthly precipitation departures for the three months centered on the month of interest. For example, the January pattern shows the correlation between the January values of the teleconnection index and the monthly precipitation departures during December, January, and February.

Student Notes:



12. What is the Arctic Oscillation (AO)?

Instructor Notes: The AO is a pattern in which atmospheric surface pressure at polar and middle latitudes fluctuates between negative and positive phases. The negative phase brings higher-than-normal pressure over the polar region and lower-than-normal pressure at about 45 degrees north latitude. The negative phase allows cold air to plunge into the Midwestern United States and western Europe, and storms bring rain to the Mediterranean. The positive phase brings the opposite conditions, steering ocean storms farther north and bringing wetter weather to Alaska, Scotland and Scandinavia and drier conditions to areas such as California, Spain and the Middle East. In recent years research has shown, the AO has been mostly in its positive phase. Some researchers argue that the North Atlantic Oscillation is in fact part of the AO. If you think about the differences, it's really only the fact that for AO the pressure differences are taken further north than that of the NAO. The bottom line is: The effects on US weather should be basically the same.

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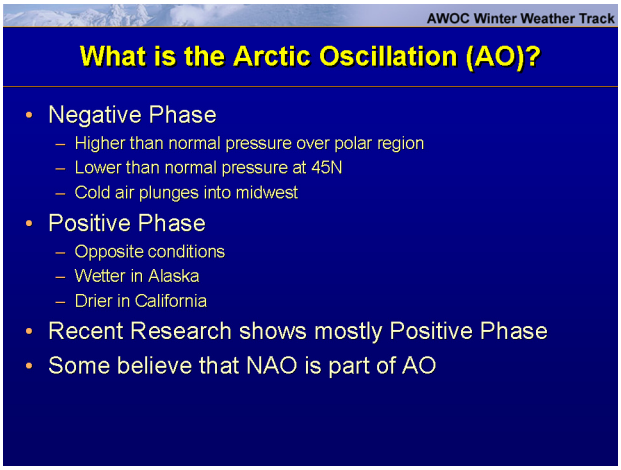

13. What are the Global AO Patterns?

Instructor Notes: Here is a conceptual model of the AO adapted from the University of Washington. You can see here that in the positive phase, there are more storms across the north Atlantic into northern Europe, and stronger trade winds off the African continent and into the eastern Atlantic. During the negative phase, you see the colder air into the midwest and Europe. (note: figure from http://nsidc.org/arcticmet/patterns/arctic_oscillation.html)

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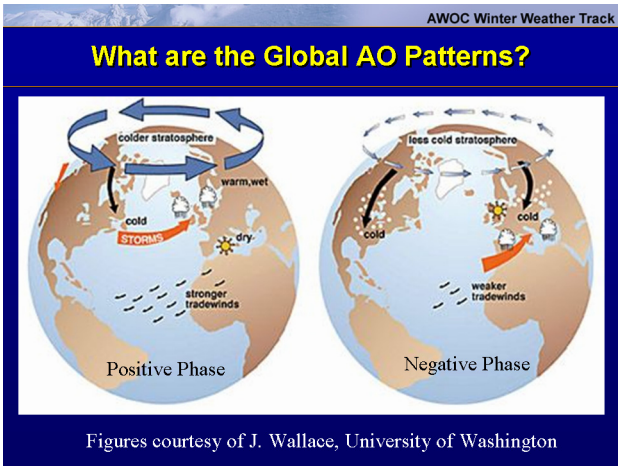

14. What are the AO Characteristics at 500 mb?

Instructor Notes: This diagram is the 500 mb heights and anomalies for different phases of the Arctic Oscillation. The top image shows the heights lines at 500 mb, with the shading being the anomalous (shaded) 500 mb height values when the AO is in the positive phase. The middle image shows AO neutral conditions, and the bottom image is AO negative anomalies at 500 mb. Note the lower than normal heights in the northern hemisphere polar region when the AO is in the positive phase, and the above normal heights in Pacific basin and the eastern US and into the Atlantic basin and Europe. During the negative phase you see the lower than normal heights over the midwest and Atlantic and Pacific basins, with the polar region and northern Atlantic having above normal heights. (note figure from http://www.cpc.ncep.noaa.gov/research_papers/ncep_cpc_atlas/8/table_ao.html)

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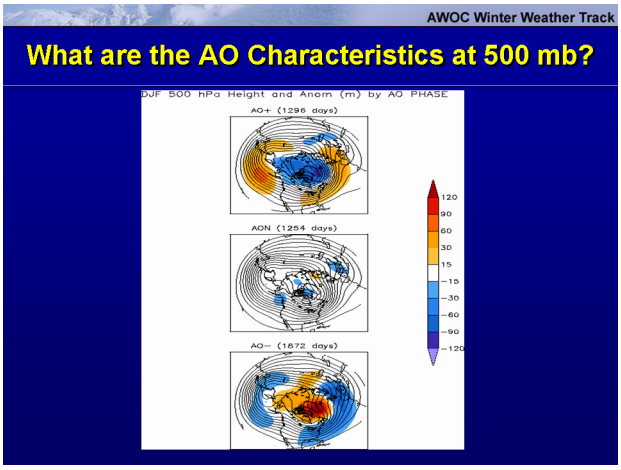
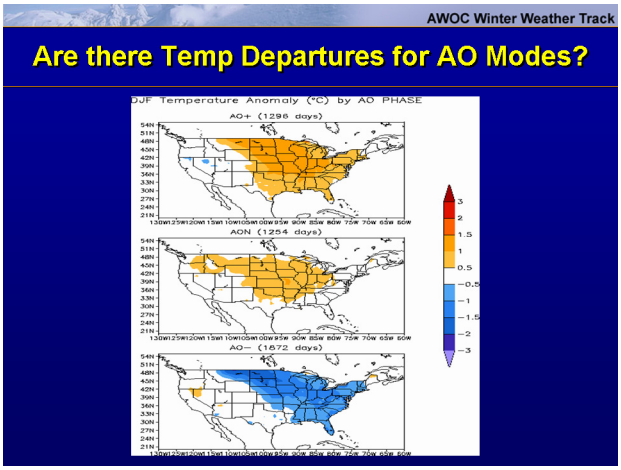


15. Are there Temp Departures for AO Modes?

Instructor Notes: The top image shows US temperature anomalies in DJF for AO+. The middle is for AO neutral. The bottom image shows surface temps when AO is negative. (figure from http://www.cpc.ncep.noaa.gov/research_papers/ncep_cpc_atlas/8/table_ao.html)

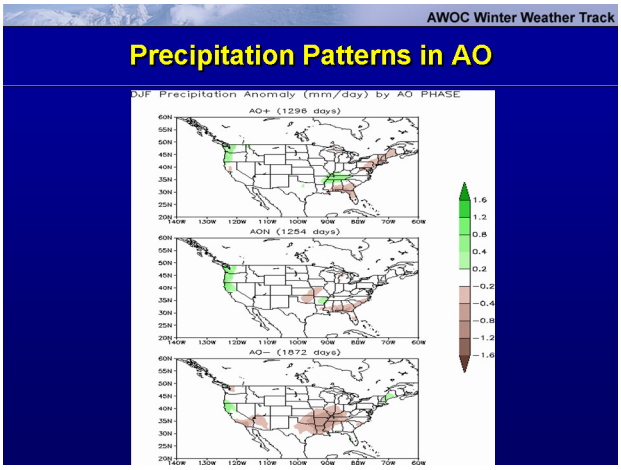
Student Notes:



16. Precipitation Patterns in AO

Instructor Notes: This image shows precipitation patterns associated with different phases of AO. The top diagram is for positive phase, the middle is for neutral and the bottom is for negative. Notice the biggest area with the most contrast between positive and negative is in the southeast US. Precipitation tends to be a much more “noisy” signal in many studies of climate variability. (note: figure from http://www.cpc.ncep.noaa.gov/research_papers/ncep_cpc_atlas/8/table_ao.html)

Student Notes:



17. Monitoring AO

Instructor Notes: In order to monitor and predict the phases of teleconnection patterns, indices have been developed such as you see here. The daily AO index is constructed by projecting the daily (00Z) 1000mb height anomalies poleward of 20°N onto AO loading pattern (climatology) that we discussed previously. Since the AO has the largest variability during the cold season, the loading pattern primarily captures characteristics of the cold season AO pattern, which you saw in the height and temperature patterns on previous slides.The daily AO index and its forecasts using GFS and Ensemble mean forecast data are shown for the previous 120 days, so in this case the plot is from the beginning of August to late November. Each daily value has been standardized by the standard deviation of the monthly AO index from 1979-2000. You can see that as mentioned previously, the AO has been mostly in a positive phase. You can read more about the construction of the AO index at the website listed at the bottom of this slide. (note: figure from http://www.cpc.noaa.gov/products/precip/CWlink/daily_ao_index/ao_index.html)

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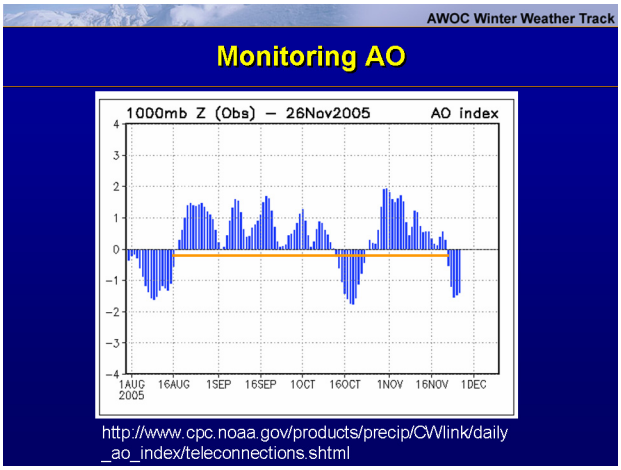

18. AO References

Instructor Notes: Here are a list of web sites you can visit to get more information on the Arctic Oscillation.

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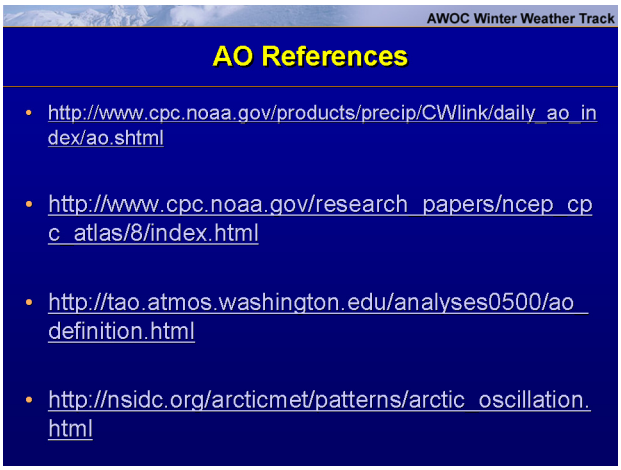

19. Teleconnection Quiz #1

Instructor Notes: Take a few moments to complete this interactive quiz.

Student Notes:

20. North Atlantic Oscillation (NAO)

Instructor Notes: The NAO is a large-scale fluctuation in atmospheric pressure between the subtropical high pressure system located near the Azores in the Atlantic Ocean and the sub-polar low pressure system near Iceland and is quantified in the NAO Index, which we will discuss further in just a minute. The surface pressure drives surface winds and wintertime storms from west to east across the North Atlantic affecting climate from New England to western Europe, and as far eastward as central Siberia and the

eastern Mediterranean and southward to West Africa. It is considered either “the largest” or “one of the largest” oscillations in the Northern Hemisphere. It is a large-scale mode of natural climate variability having large impacts on weather and climate in the North Atlantic region and surrounding continents. It is most pronounced during winter and accounts for more than one-third of the total variance in sea-level pressure (Cayan, 1992a) The link at the bottom of the page is a tutorial from Columbia University.

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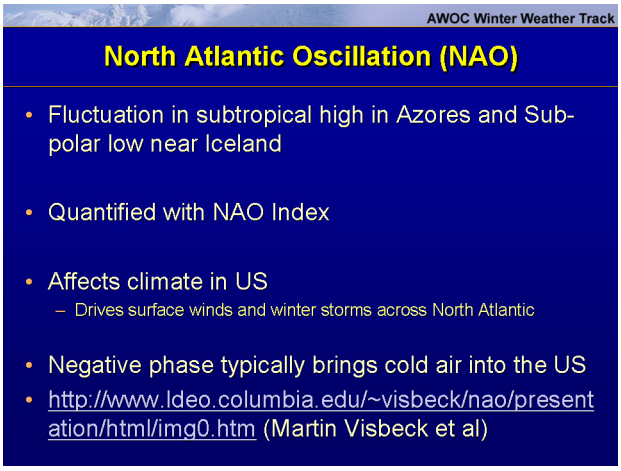

21. What’s a Positive NAO Look Like?

Instructor Notes: Here is a picture of the NAO in it’s positive phase with Low pressure over Greenland and subtropical high pressure entrenched over the Azores. You can see the wetter than normal conditions that prevail over the eastern third of the US and into northern Europe and Siberia, while drier than normal conditions occur in the Mediterranean region. (note: figure from http://www.ldeo.columbia.edu/NAO/main.html)

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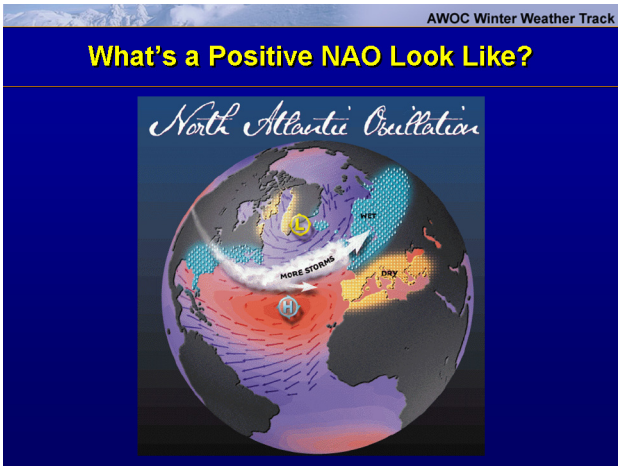

22. What's a Negative NAO Look Like?

Instructor Notes: In the negative phase of the NAO, the lows and highs mentioned previously are much weaker. Colder air intrudes into the eastern US, but drier conditions prevail there as well as in northern Europe and into Siberia. Wetter conditions are seen in southern Europe and the Mediterranean. (NOTE: Figure from http://www.ldeo.columbia.edu/NAO/main.html)

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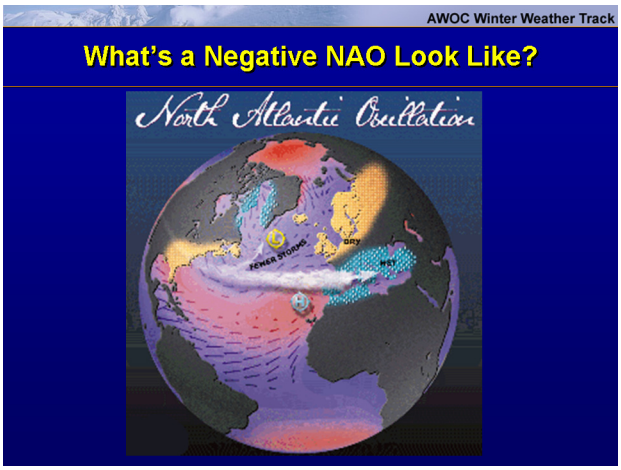
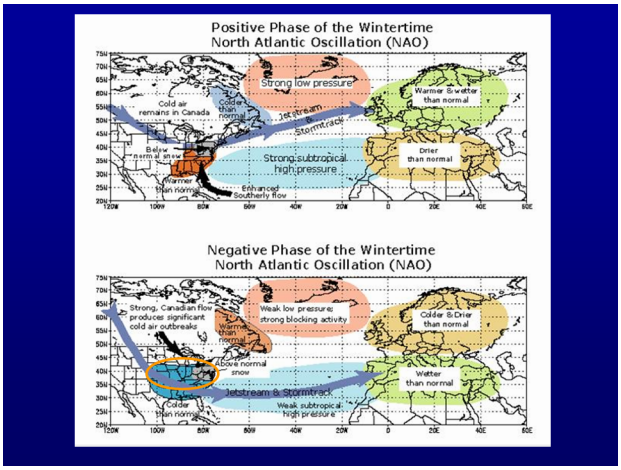


23. Phases of the Wintertime NAO

Instructor Notes: Here are typical conditions over the Atlantic and associated land masses. You can see the effects of the jet stream during the positive phase (top drawing) and the negative phase (bottom drawing). Notice the increased meridional nature of the jet over the lee side of the Rockies in the negative phase, which allows for increased intrusions of cold air into the eastern ½ of the US.

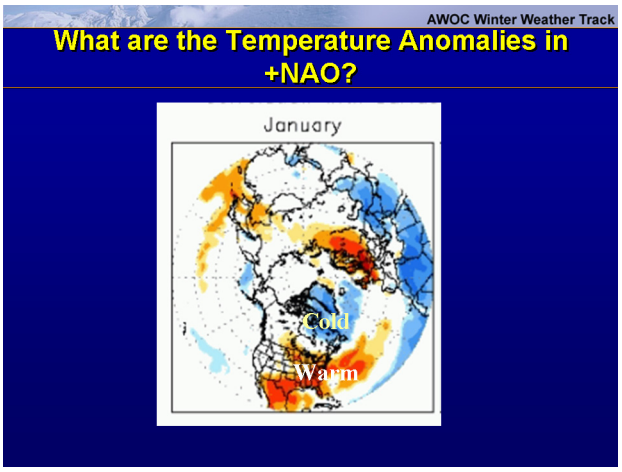
Student Notes:



24. What are the Temperature Anomalies in +NAO?

Instructor Notes: During the positive phase of the NAO, cold air remains over Canada, and warmer temps are seen over much of the continental US, especially in the eastern half and along the deep south. In the negative phase (not shown) Canadian air is allowed into the US and so the orange is replaced by blue.

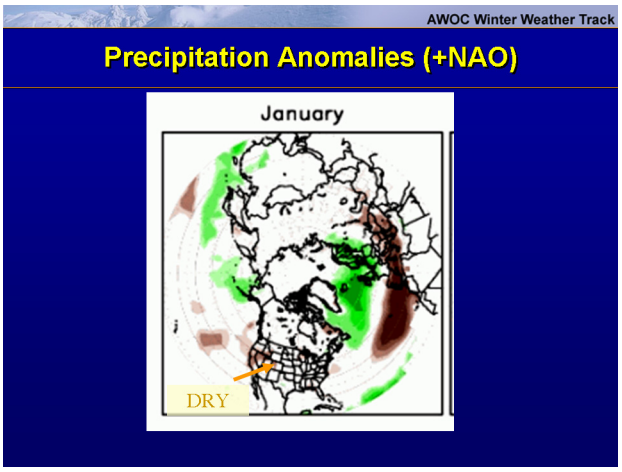
Student Notes:



25. Precipitation Anomalies (+NAO)

Instructor Notes: As we saw in AO, the precipitation signals for the US in +NAO (or -NAO for that matter) are not strong. Much stronger signals show up southeast of Iceland (wetter in +NAO) and the Mediterranean (drier in +NAO). There are somewhat drier conditions noted in the western US and into the eastern Pacific. Meanwhile somewhat wetter conditions prevail along the Aleutian chain and into the Bering Sea.

Student Notes:



26. Monitoring NAO

Instructor Notes: The daily NAO index corresponds to the NAO patterns, which vary from one month to the next. This index, like that for other teleconnection patterns is derived through a mathematical expression that considers a time series of atmospheric parameters (such as 500 mb heights in this case). The link at the bottom of this slide has further information about the methodology used to calculate the daily NAO index. The daily NAO index for the past 120 days is shown in this diagram. Each daily value has been standardized by the standard deviation of the monthly NAO index from 1950 to 2000.

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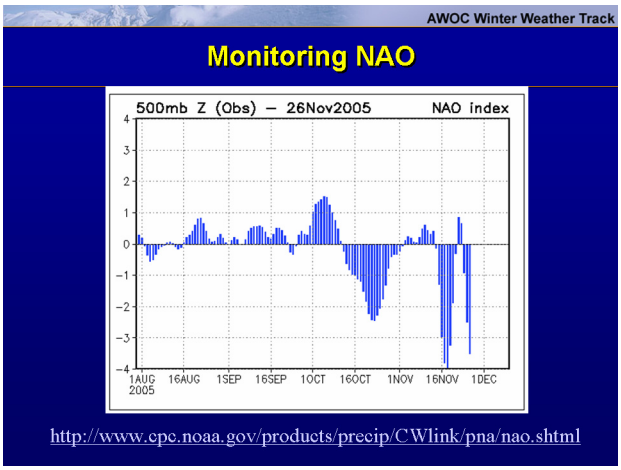
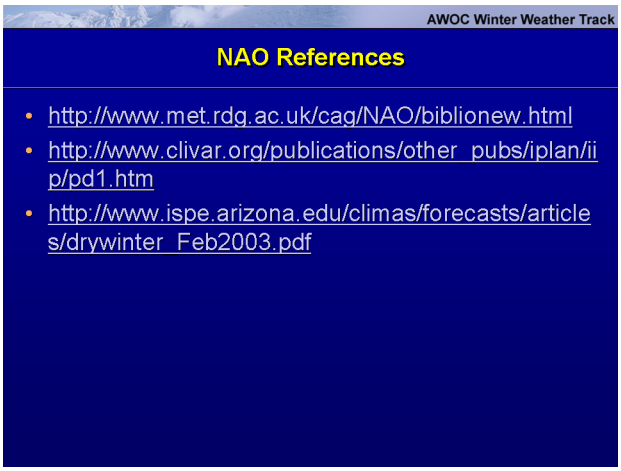


27. NAO References

Instructor Notes: Here are a few references on the NAO.

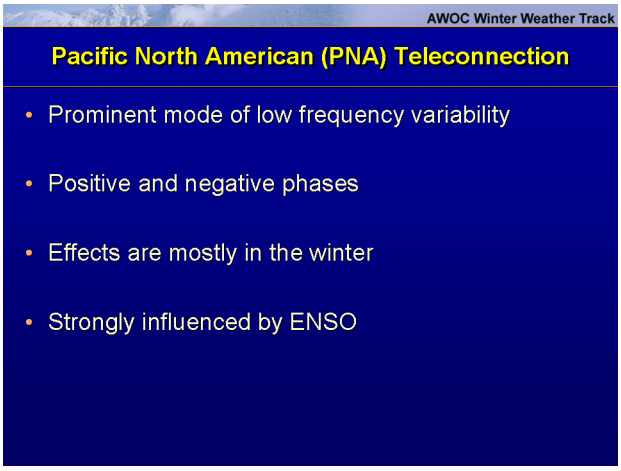
Student Notes:



28. Pacific North American (PNA) Teleconnection

Instructor Notes: The Pacific/ North American teleconnection pattern (PNA) is one of the most prominent modes of low-frequency variability in the Northern Hemisphere extra-tropics. Although the PNA pattern is a natural internal mode of climate variability, it is also strongly influenced by the El Niño/ Southern Oscillation (ENSO) phenomenon. The positive phase of the PNA pattern tends to be associated with Pacific warm episodes (El Niño), and the negative phase tends to be associated with Pacific cold episodes (La Niña).

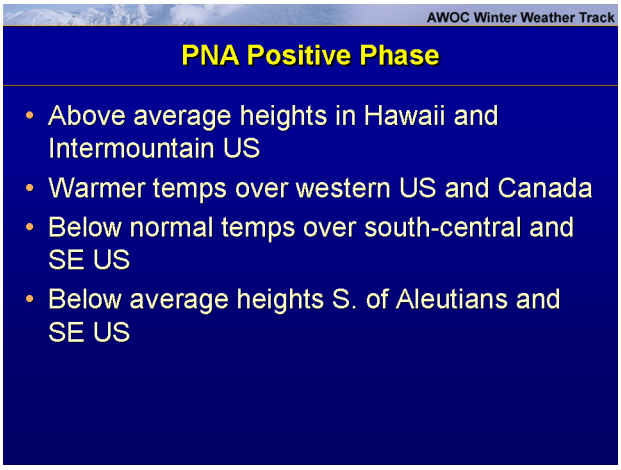
Student Notes:



29. PNA Positive Phase

Instructor Notes: The positive phase of the PNA pattern features above-average heights in the vicinity of Hawaii and over the intermountain region of North America, and below-average heights located south of the Aleutian Islands and over the southeastern United States. The PNA pattern is also associated with strong fluctuations in the strength and location of the East Asian jet stream. The positive phase is associated with an enhanced East Asian jet stream and with an eastward shift in the jet exit region toward the western United States. The positive phase of the PNA pattern is associated with above-average temperatures over western Canada and the extreme western United States, and below-average temperatures across the south-central and southeastern U.S., particularly during the wintertime. The associated precipitation anomalies include above-average totals in the Gulf of Alaska extending into the Pacific Northwestern United States, and below-average totals over the upper Midwestern United States.

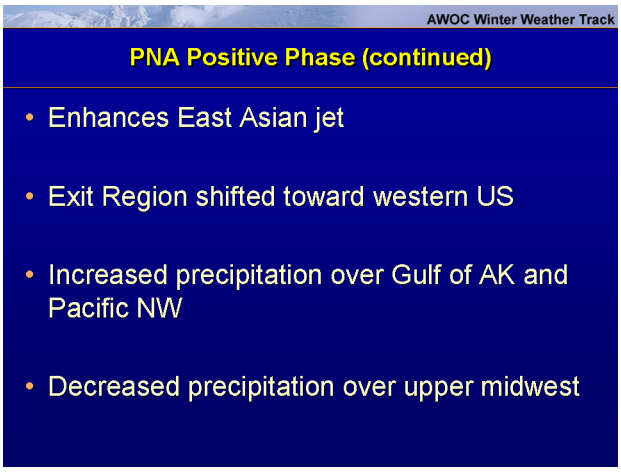
Student Notes:



30. PNA Positive Phase (continued)

Instructor Notes: Some of the other effects of the PNA are an enhancement in the east Asian jet which can enhance storm systems that enter the western US by the exit region of the East Asian (EA) jet. Also, increased vertical motion can be found over the Gulf of AK courtesy of this enhanced EA jet. Meanwhile, the upper Midwest of the US will have more ridging which will mean drier and warmer conditions there.

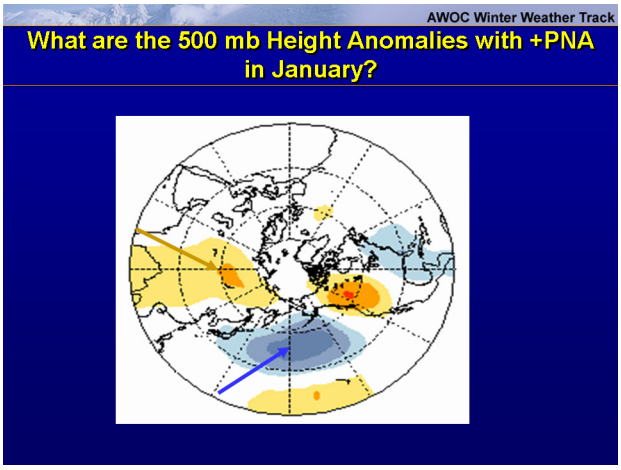
Student Notes:



31. What are the 500 mb Height Anomalies with +PNA in January?

Instructor Notes: Here is a diagram which shows the departures from normal of the 500 mb heights in January during a positive phase of the PNA. Notice the lower than normal heights over much of the Pacific basin, while higher than normal heights extend into the western US and Canada.

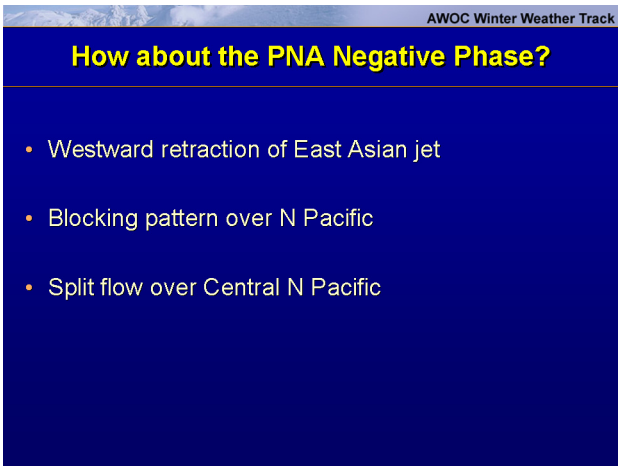
Student Notes:



32. How about the PNA Negative Phase?

Instructor Notes: During the PNA negative phase, the EA jet will retrograde back westward which will result in a blocking ridge over the North Pacific. This tends to lead to a split jet over the central Pacific and into the western US.

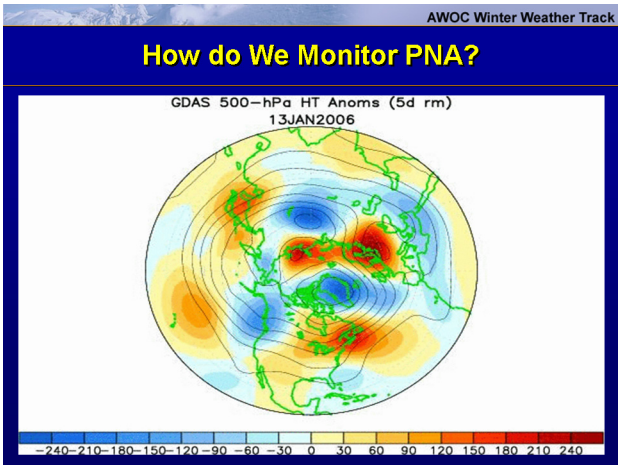
Student Notes:



33. How do We Monitor PNA?

Instructor Notes: To monitor the PNA, we look at 500-hPa heights and anomalies. If significant departures are noted in the height patterns, we determine that the PNA teleconnection is in a positive or negative phase. To better see the phase, like in the NAO, there is a index that is plotted on CPC's web site. On the web site, there is an animation with each frame being a five-day mean, centered on the date indicated in the title, of 500-hPa heights and anomalies from the NCEP Global Data Assimilation System (GDAS). Contour interval for heights is 120 m, anomalies are indicated by shading. Anomalies are departures from the 1979-95 daily base period means.

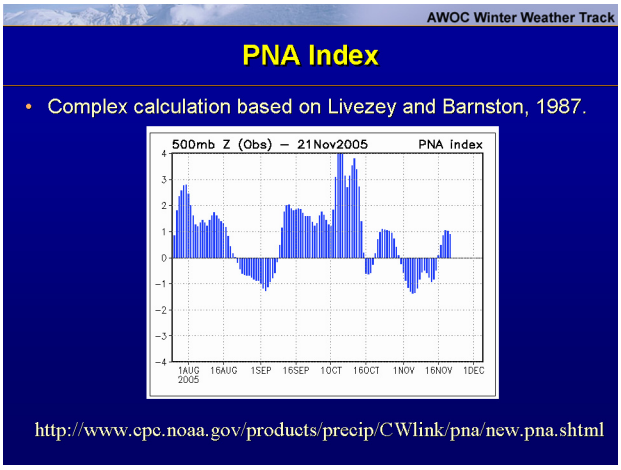
Student Notes:



34. PNA Index

Instructor Notes: The procedure used to calculate the daily PNA and NAO teleconnection indices is based on the Rotated Principal Component Analysis (RPCA) used by Barnston and Livezey (1987, Mon. Wea. Rev., 115, 1083-1126). This procedure isolates the primary teleconnection patterns for all months and allows time series of the patterns to be constructed. To obtain the teleconnection patterns, the RPCA technique is applied to monthly standardized 500-mb height anomalies between January 1950 and December 2000. The monthly teleconnection patterns are now linearly interpolated to the day in question, and therefore account for the seasonality inherent in the NAO and PNA patterns. The daily teleconnection indices are now calculated using the Least Squares regression approach identical to that used for the monthly indices. Therefore, all of the teleconnection patterns valid for the day in question are now recognized when calculating the PNA and NAO indices. The daily indices now represent the combination of teleconnection patterns that accounts for the most spatial variance of the observed anomaly map on any given day. Previously, the indices represented the spatial correlation between the annual mean loading pattern of the NAO or PNA and the daily height anomalies, and did not account for the spatial overlap that exists amongst the various teleconnection patterns.

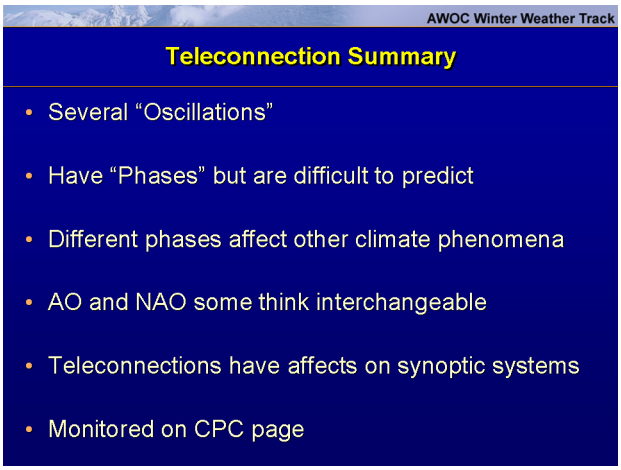
Student Notes:



35. Teleconnection Summary

Instructor Notes: "Teleconnections" are atmospheric relationships that are measured by looking at different levels in the atmosphere and comparing the current state with the "normal" through complex mathematics. The mode that a particular teleconnection is in is called a "phase". There are positive and negative "phases" each of which have ramifications to the synoptic scale weather patterns. We will discuss more about the monitoring of teleconnections in the next section called CPC/CDC products.

Student Notes:



36. Teleconnections Quiz #2

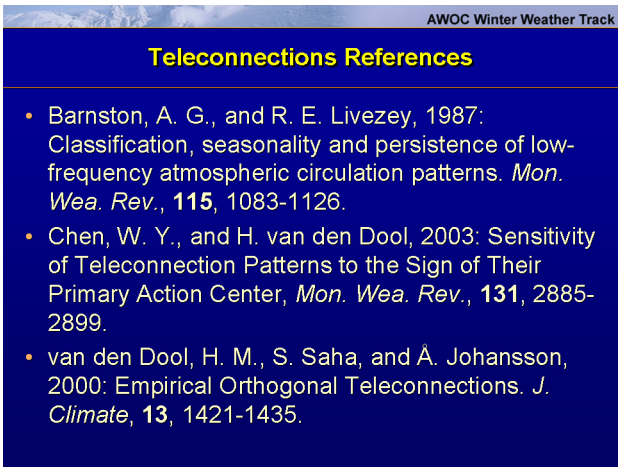
Instructor Notes: Take a few moments to complete this interactive quiz.

Student Notes:

37. Teleconnections References

Instructor Notes: Here are some references on teleconnections.

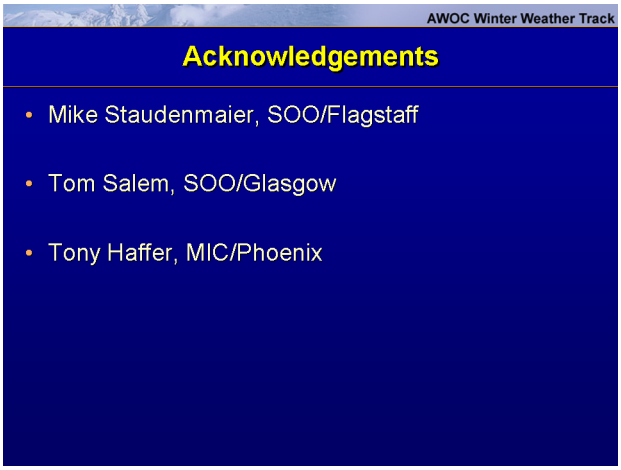
Student Notes:



38. Acknowledgements

Instructor Notes: I'd like to thank the following individuals for the support in creating this section: Mike Staudenmaier, SOO/Flagstaff, Tom Salem, SOO/Glasgow, Tony Haffer, MIC/Phoenix

Student Notes:



39. Questions???

Instructor Notes: After going through this lesson if you have any questions, first ask your SOO. Your SOO is your local facilitator and should be able to help answer many questions. If you need additional info from what your SOO provided, send an E-mail to the address on the slide. This address sends the message to all the instructors involved with this IC. Our answer will be CC'd to your SOO so that they can answer any similar

questions that come up in the future. We may also consider the question and answer for our FAQ page.

Student Notes: